CoOp Agreement

Idaho Department
of Health
& Welfare

SEDIMENT MONITORING TECHNIQUES
VALIDATION YEAR 1

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PROGRESS REPORT

SEDIMENT MONITORING TECHNIQUES VALIDATION

YEAR 1

Prepared for

Idaho Department of Health and Welfare
Division of Environmental Quality
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by

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EXECUTIVE SUMMARY

In April, 1990, we began research to evaluate artificial redd monitoring as a technique to measure the effect of fine sediment on beneficial uses of streams. Project objectives are to: 1) measure temporal changes in fine sediment, intergravel dissolved oxygen, egg and alevin survival in natural and artificial redds and 2) determine if differences between natural and artificial redds are statistically significant. This report describes field research conducted through June 30, 1990.

We began investigating pre-emergent steelhead trout redds in the mainstem Salmon River and post-emergent chinook salmon redds in the South Fork Salmon River. Within the mainstem Salmon River, we selected four types of sampling sites: natural steelhead trout redds, artificially constructed redds, sites in substrate outside of redds, and sites with artificially cleaned substrate. We measured the following physical parameters and compared them between the sites: surface depths and velocities, intergravel dissolved oxygen, intragravel velocity, and particle size distribution. Within the South Fork Salmon River, we measured the particle size distribution in natural; chinook salmon redds and in sites outside of redds. Field research will continue through May 1991. A report describing the results of the initial year of research will be prepared in 1991.

INTRODUCTION

The Idaho Health and Welfare Department has developed field techniques to measure the effects of sediment on beneficial uses of streams. Two of these techniques, artificial redd monitoring and quantitatively measuring cobble embeddedness, have been used to assess the condition of salmonid spawning sites and juvenile rearing habitats. These measures have not had the necessary validation to demonstrate whether they are appropriate methods for quantifying sediment effects on spawning and rearing habitats.

This report describes the progress made toward the validation of artificial redd monitoring techniques. We will conduct additional field evaluations of artificial redds through May, 1991. Field assessment of cobble embeddedness techniques will commence in September 1990. A report describing results of the initial year of research will be prepared in June 1991.

OBJECTIVES

1. To measure temporal changes in fine sediment, intergravel dissolved oxygen, egg and alevin survivial in natural and artificial redds.

2. To determine if differences in the above referenced parameters between natural and artificial redds are statistically significant.

DESCRIPTION OF THE STUDY AREA

Research is being conducted in two different drainages in south central Idaho. We are investigating pre-emergent steelhead trout (Onchorhynchus mykiss) redds in the mainstem Salmon River and post emergent chinook salmon (Ohnchorhynchus tshawytscha) redds in the South Fork Salmon River (SFSR).

The mainstem Salmon River study area is located approximately 19 km upstream from Stanley, Idaho is a 1.6 km reach near the confluence of Hell Roaring Creek. The river flows northward and drains over 500 km^2 of the White Cloud and Sawtooth mountains on the Sawtooth National Forest. While the mountains on along the divides are steep and rocky, the valley along the Salmon River is broad and composed of alluvium and glacial deposits. The geology is predominately granitic with a small portion of Paleozoic sedimentary rock in the southeast portion of the basin. Elevations range from 1950m at the study reach to over 3050m along the divides. Within the study reach, gradients range between 3 and 5%. The predominant hydrologic event occurs during the spring snowmelt period from April through June when flows may reach 50 to 100 times the base flows attained from September through January.

The South Fork Salmon River study site is located in the Poverty Flat spawning reach near the confluence of Blackmare Creek. From its orgin, the river flows north and joins the mainstem Salmon River 7.7 km upstream from Riggins, Idaho. The SFSR flows through the central Idaho Batholith, an area of granitic bedrock. The granitic bedrock is highly weathered at the lower elevations resulting in highly erodible soils. Bedload transport of sand sized materials has a pronounced effect on the channel substrate. Peak stream discharge typically occurs in a six week period in May and June during snowmelt. Base flows occur from September through January.

METHODS

Pre-emergent steelhead trout redds

Thirty pair of hatchery reared steelhead trout were obtained from the Idaho Department of Fish and Game's Pahsimeroi hatchery. The fish were released in the mainstem Salmon River near the confluence of Hell Roaring creek on April 20, 1990. Within 4 days we identified 29 new redds, 13 in a diversion channel adjacent to the river and 0.8 km downstream from the release site and 16 near the mouth of Hell Roaring Creek. Subsequent reference to these two locations will be the Diversion reach and the Hell Roaring reach. Ten redds were randomly selected at each of the two sites. An additional six redds were selected at the Hell Roaring reach to serve as extra sites in the event that other instrumented redds were destroyed.

We applied terminology described by Grost (1989) as follows: redd -an area of the substrate modified by a salmonid during reproduction, usually elliptical and composed of a pit and tailspill. Pit- the deeper, concave, upstream portion of the redd. Tailspill- the shallower, convex, downstream portion of the redd. Egg pocket- a concentration of eggs within the redd. Centrum- one or more large rocks associated with an egg pocket.

On April 24, 1990 dissolved oxygen monitoring probes were inserted into the redds from the downstream end of the pit and at the boundary of the undisturbed substrate and tailspill. We attempted to insert the probes adjacent to the egg pockets within the redds. The probes are constructed of continuous coil slot well screen (30.5 cm of 3.2 cm diameter) capped on both ends with PVC fittings. An inner perforated rigid tube is attached to a 152cm length of 6.3mm (inside diameter) flexible tubing (Burton et al 1990). The probes were inserted and the flexible tubing left exposed above the substrate.

Associated with each redd, three additional sampling sites were randomly selected; one for construction of an artificial redd, one for sampling the substrate outside of redds, and one for measuring the intrusion rate of fine sediments into the substrate. We established four 3mx3m quadrants around each natural redd. One quadrant was randomly selected for the artificial redd site. Within the selected quadrant three sites were chosen that met the following criteria for steelhead spawning sites: water depth of 0.37 to 0.60m, velocity of 0.5 to 0.65 m/s, and a substrate with diameters of 0.3 to 7 cm with 10 to 25% cobble (Cochnauer and Elms, 1986). The sites for the natural substrate sampling and sediment intrusion sampling were similarly randomly located in the remaining quadrants. Occassionally, no sites within a quadrant or quadrants met the depth, velocity, and substrate criteria, and multiple sampling sites were located within one quadrant. In all cases, sampling sites were located to minimize any sampling disturbance on the natural redd.

At the sediment intrusion sites, substrate was excavated to a depth of at least 30 cm and a diameter of approximately 38 cm. The excavated substrate was sieved through a 6.35 mm mesh sieve and the material smaller than 6.35mm diameter discarded. A 40cm high by 30.5 cm diameter bucket (Lisle 1990) was placed in a collapsed position in the bottom of the excavation and buried with the "cleaned substrate". Collapsible buckets could not be installed in the Diversion reach due to the depth of the water; however, 16 were installed at the Hell Roaring reach.

Artificial redds were constructed on April 24th with the assistance of Idaho Department of Environmental Quality personnel who had previous experience in constructing artificial redds. An egg basket and dissolved oxygen probe were placed in each artificial redd. Burton et al (1990) describes the specific techniques of artifical redd construction and the construction and installation of egg baskets. In brief, artificial redds are constructed by excavating a depression with a shovel. The gravel is lifted into the current and released. A depression and a downstream tailspill develop as excavation continues. An 30.5cm by 15cm diameter egg basket is filled with substrate from the tailspill surface, placed in the depression and then buried as excavation continues upstream. Excavation depth is 30 to 40cm. Excavation continues until a pit about 1m long develops. The egg baskets are constructed of PVC net lined with nylon net with a mesh diameter of 3.7mm. A length of 1.9cm diameter PVC pipe placed vertically in the egg basket during filling, facilitated later implantation of eggs. Three copper tubes were also placed vertically in the egg baskets to facilitate later freeze coring. We obtained water hardened hatchery steelhead trout eggs from the Idaho Department of Fish and Game and inserted 100 in each egg basket. Eggs were funneled into the PVC pipe as the tube was slowly extracted in order to deposit eggs vertically throughout the egg basket.

Selected physical measurements were made of all the natural and artificial redds to characterize similarities and differences and determine variances. Parameters measured included the depth of water over the tailspill, the depth of water over the pit, pit width and length, tailspill width and length, and stream velocity over the pit and tailspill at a depth 0.6 times the total depth. Measurements made at the natural redds, artificial redds, outside redd sampling sites, and sediment intrusion sites included the initial stream depth and stream velocity. Measurements were made with a Marsh-McBirney current meter.

The dissolved oxygen content of water within the natural and artificial redds was sampled at 2 week intervals from redd construction. We extracted water samples from the probes through the flexible tubing with a hand activated vacuum pump. Approximately 250ml of water was initially extracted to cleanse the probe and measure the water temperature. A second extraction was used to fill a 300 ml BOD bottle. Dissolved oxygen content was determined in the field using the modified Winkler procedure. Percent saturation was determined using standard procedures to correct for water temperature and elevation.

The dissolved oxygen probes were also used to determine an index of the intergravel velocity within the natural and artificial redds. These determinations were made monthly on those artificial and natural redds selected for freeze coring. A thin tube was inserted through the flexible tube on the dissolved oxygen probe and into the probe itself. A 50ml sample of water was extracted using a syringe and the specific conductance of the water was measured. Next, 50ml of 0.05M NaCl solution was injected into the probe. Fifty ml samples were extracted at 2 and 5 minutes intervals and the specific conductance was measured. Samples were placed in vials and frozen for later laboratory determination of sodium and chloride concentrations. The specific conductance was used to calculate the sodium ion concentration. The ratio of the sodium concentration of the samples extracted at 2 and 5 minutes was used as an index of the apparent velocity within the substrate. This procedure assumes that the rate of salt dilution

within the probes is proportional to the intergravel velocity. This assumption must eventually be verified in the laboratory. As the value of this index increases the intergravel velocity should also increase.

Two natural redds were selected for detailed measurements of depths below the water surface and water velocities. This data will be used to measure changes in redd morphology during the incubation period. At monthly intervals a PVC frame was placed over each redd and depths and velocities measured on a 20cm by 20cm grid. We measured substrate size at each grid point at the initial measurement and we will re-measure substrate after incubation is completed.

We collected substrate samples to characterize the particle size distibution in the sampling sites. At monthly intervals, we randomly selected two natural redds, two artificial redds, and two outside redd sites each in the Diversion and Hell Roaring reaches for freeze coring. Additionally, four intrusion sites were chosen at the Hell Roaring site for freeze coring and extraction of the collapsible bucket. A tri-tube freeze coring procedure using liquid CO_2 (Everest, et al 1980) was used to extract a vertical substrate sample from the tailspill and pit in natural redds, the egg baskets in the artificial redds and at the surrounding substrate and intrusion sites. Using definitions proposed by Young et. al. (1989), we labelled cores as egg-pocket samples if we observed eggs or alevins in the core. The samples were laid horizontally on a sheet metal tray and subsampled into 10cm strata. A propane torch facilitated the melting process.

The sediment core samples were air dried and sieved through the following mesh sizes: 128, 64, 32, 16, 9.5, 8, 6.35, 4, 2, 1, .85, .5, ..25, .125, and .063mm. We calculated three indices to relate sediment composition to other redd parameters including: the percentage of material less than 6.35mm, the Fredle index (Lotspeich and Everest 1981) and the geometric mean diameter. These indices were determined for the individual vertical substrata and for the composite freeze core. Since the freeze core technique did not work well for the instrusion site, these indices were calculated for the sample extracted in the collapsible bucket.

<u>Post-emergent chinook salmon redds</u>

On April 3, 1990 twenty five chinook salmon redds were identified in the Poverty Flat spawning reach of the SFSR. The location of the redds was surveyed into existing permanent stakes along the shoreline. The tailspill length was measured for each redd. On June 5, following chinook salmon fry emergence and the completion of steelhead spawning, fifteen chinook redds were selected for substrate analysis. Ten redds were rejected either because they were affected by steelhead trout spawning activity or because they were adjacent to newly constructed steelhead trout redds. Adjacent to each chnook salmon redd, we selected one site for sampling the natural substrate outside the redd. We applied the same random selection procedure described in the pre-emergent steelhead trout section in the Poverty reach.

Two freeze cores of substrate were extracted from each redd, one from the tailspill and one from the pit. One freeze core was extracted from each of the surrounding substrate sites. We employed the same field procedures and laboratory procedures are described in the preceding section of this report. The cores from the Poverty reach have not yet been sieved to determine their partical size distribution.

DATA

Compiled data are displayed in this section of the Progress Report. Because research is continuing, this information should be considered preliminary. We have made no attempt to thoroughly analyze the data or present results. If trends are apparent, we have attempted to illustrate them. Thorough compilation of the information, statistical analysis, correlation of variables, and discussion of results will be presented in a future report.

Initial Physical Conditions

Tables 1 and 2 list the depths and velocities for the natural and artificial redds and the subtrate and intrusion sampling sites. Since the natural redds were in place at the time these measurements were made, we measured depths and velocities just upstream of the pits. The depths of the natural redds averaged 58.00 and 49.6 cm for the Diversion and Hell Roaring reaches, respectively. In the Hell Roaring reach, the depths were similar for the artificial redds, natural redds, substrate sites, and the intrusion sites. In the Diversion reach the artificial redds and substrate sites averaged about 8cm shallower than the natural redds. Velocities for the natural redds averaged .92 and .83 m/s for the Diversion and Hell Roaring reaches, respectively. Velocities were slightly higher for the natural redds at the Hell Roaring reach than the artificial redds, intrusion sites or substrate sites. In the Diversion reach, velocities were appreciably greater in the natural redds, averaging .23 m/s and .13 m/s greater than the artificial redds and substrate sites, respectively.

Table 3 lists the water depths over the pits and tailspills and the water velocities after redd construction. The water depths over the pits and tailspills in the natural redds in the Diversion reach averaged about 7 and 12cm greater than the artificial redds. At the Hell Roaring reach, the natural redds had depths over the pits about 7cm less than the artificial redds, but averaging about 4cm more depth over the tailspill than the artificial redds. Velocities over the pits in the natural redds averaged .81 and .76 m/s for the Diversion and Hell Roaring reaches, respectively, compared to .58 and .62 m/s for the artificial redds.

Table 4 lists the widths and lengths of the pits and tailspills for the natural steelhead trout redds and the artificial redds. In general, the width and length of the artificial redd pits and tailspills averaged less than those of the natural redds.

Table 1. Stream depths and velocities immediately upstream of the pits in steelhead trout redds shortly after construction and at sites just prior to construction of artificial redds in the Salmon River near Stanley, April 24, 1990.

	NATURAL REDDS			ARTIFICIAL REDDS		
	Redd Id	Upstream Depth	Upstream Velocity	Redd Id	Initial Depth	Initial Velocity
		cm	m/s		cm	m/s
DIVERSION						
	DR1	52	.67	DA1	52	.94
	DR3	52	1.10	DA2	30	.79
	DR4	49	1.16	DA3	55	.82
	DR5	61	1.03	DA4	46	.82
	DR8	58	.90	DA5	56	.60
	DR9	58	.98	DA6	49	.55
	DR10	61	.98	DA7	46	.70
	DR11	70	.85	DA8	49	.68
	DR12	61	.79	DA9	52	.52
	DR13	58	.72	DA10	61	.52
	MEAN	58.0	.92		49.6	.69
	ST.DEV	6.00	.16		8.32	.15
HELL ROARING						
	HR3	41	.91	HA1	43	1.03
	HR4	37	.83	HA2	43	.79
	HR6	49	.91	HA3	43	.79
	HR9	46	.76	HA4	53	.63
	HR10	46	.68	HA5	30	1.06
	HR11	40	.93	HA6	35	.73
	HR14	27	.80	HA7	27	.76
	HR15	30	.80	HA8	30	.59
	HR16	30	.86	HA9	27	.72
	HR17	30	.80	HA10	37	.73
	MEAN	37.6	.83		36.8	.78
	ST.DEV	7.99	.08		8.60	.15
COMBINED						
	MEAN	47.8	.87		43.2	.74
	ST.DEV	12.52	.13		10.53	.15
EXTRA						
	HR5	34	.87			
	HR8	34	.94			
	HR13	43	.83			
	HR18	26	.80			
	HR20	41	.81			
	HR22	34	.51			
	MEAN	35.3	.79			
	ST.DEV	6.06	.15			

Velocities and depths for natural redds were measured just upstream from the pit about two to four days after redd construction.

Velocities are measured at 0.6xdepth from the water surface.

Table 2. Stream depths and velocities at the surrounding substrate sampling sites and the sediment intrusion sites in the Salmon River near Stanley, April 24, 1990.

	SUBSTRATE SITES			INTRUSION SITES		
	Site Id	Initial Depth	Initial Velocity	Site Id	Initial Depth	Initial Velocity
		cm	m/s		cm	m/s
DIVERSION						
	DS1	55	.78	NO INTRUSION SITES		
	DS2	58	1.04			
	DS3	43	1.01			
	DS4	52	.78			
	DS5	52	.80			
	DS6	40	.87			
	DS7	52	.70			
	DS8	34	.59			
	DS9	56	.71			
	DS10	59	.62			
	MEAN	50.1	.79			
	ST.DEV	8.32	.15			
HELL ROARING						
	HS1	52	.82	HI1	46	.87
	HS2	34	.69	HI2	44	.71
	HS3	40	.98	HI3	37	.97
	HS4	46	.50	HI4	43	.94
	HS5	34	.70	HI5	27	.98
	HS6	37	.90	HI6	34	.66
	HS7	27	.62	HI7	24	.60
	HS8	30	.64	HI8	30	.43
	HS9	30	.78	HI9	27	.74
	HS10	37	.84	HI10	34	.94
	MEAN	36.7	.75		34.6	.78
	ST.DEV	7.67	.14		7.78	.19
EXTRA						
	HS11	30	.89	HI11	34	.97
	HS12	43	.77	HI12	43	.77
	HS13	37	.92	HI13	43	.82
	HS14	46	.71	HI14	30	.61
	HS15	37	.48	HI15	40	.79
	HS16	23	.84	HI16	24	.68
	MEAN	36.0	.77		35.7	.77
	ST.DEV	8.44	.16		7.71	.12

Velocities are measured at 0.6xdepth from the water surface.

Table 3. Stream depths and velocities associated with natural and artificial steelhead trout redds in the Salmon River above Stanley, April 24, 1990.

	NATURAL REDDS					ARTIFICIAL REDDS			
Redd	Pit		Tailspill		Redd	Pit		Tailspill	
Id	Depth cm	Velocity m/s	Depth cm	Velocity m/s	Id	Depth cm	Velocity m/s	Depth cm	Velocity m/s
DIVERSION									
DR1	52	.78	40	.83	DA1	53	.82	43	1.08
DR3	61	.86	40	1.01	DA2	37	.40	18	.63
DR4	61	.97	46	1.08	DA3	62	.63	38	.98
DR5	67	.88	40	1.30	DA4	58	.42	27	.94
DR8	64	.86	52	.98	DA5	66	.59	41	.74
DR9	66	.87	46	1.06	DA6	61	.69	34	.93
DR10	70	.82	43	1.05	DA7	52	.73	30	.71
DR11	73	.72	49	.94	DA8	53	.50	34	.79
DR12	73	.76	64	.80	DA9	64	.46	41	.62
DR13	66	.58	55	.74	DA10	76	.58	49	.64
MEAN	65.3	.810	47.5	.979		58.2	.582	35.5	.806
SDEV.	6.33	.107	7.78	.163		10.4	.139	8.94	.165
HELL ROARING									
HR3	46	.99	43	1.04	HA1	55	.76	34	1.03
HR4	46	.77	30	.95	HA2	58	.95	30	1.18
HR6	52	.67	30	1.00	HA3	61	.69	34	.89
HR9	41	.72	18	.80	HA4	64	.54	37	.92
HR10	46	.89	37	.96	HA5	49	.82	17	.72
HR11	46	.80	37	.84	HA6	46	.55	26	.80
HR14	37	.58	30	.74	HA7	43	.38	15	.81
HR15	44	.68	34	.78	HA8	43	.36	18	.66
HR16	38	.74	21	.96	HA9	34	.67	18	1.04
HR17	37	.73	21	.99	HA1	52	.52	30	.92
MEAN	43.3	.757	30.1	.906		50.5	.624	25.9	.897
SDEV.	4.92	.116	8.09	.106		9.30	.189	8.24	.158
COMBINED									
MEAN	54.3	.784	38.8	.943		54.4	.603	30.7	.852
SDEV.	12.56	.112	11.80	.139		10.38	.163	9.71	.164
EXTRA									
HR5	43	.86	30	1.06					
HR8	38	.74	23	1.00					
HR13	47	.74	34	.87					
HR18	32	.82	21	1.00					
HR20	53	.68	35	.80					
HR22	43	.49	30	.64					
MEAN	42.7	.722	28.8	.895					
SDEV.	7.23	.130	5.71	.157					
ALL REDDS									
MEAN	48.4	.809	39.7	.932					
SDEV	15.69	.130	10.91	.142					

Velocities are measured at 0.6xdepth from the water surface.

Table 4. Widths and lengths of pits and tailspills associated with natural steelhead trout redds and artificial redds in the Salmon River near Stanley, Idaho, April 24, 1990.

	NATURAL REDDS				ARTIFICIAL REDDS				
Redd Id	Pit Length	Pit Width	Tailspill Length	Tailspill Width	Redd Id	Pit Length	Pit Width	Tailspill Length	Tailspill Width
	---------meters---------					-----------meters----------			
DIVERSION									
DR1	1.62	.85	2.11	1.25	DA1	.83	1.07	1.40	1.00
DR3	1.02	1.80	2.10	1.07	DA2	.77	.89	1.40	.82
DR4	1.10	1.00	1.59	1.13	DA3	1.23	.80	1.31	.76
DR5	1.65	1.40	2.90	1.28	DA4	1.23	.84	1.07	.70
DR8	1.01	1.19	2.39	1.28	DA5	1.33	1.13	1.57	.86
DR9	1.35	1.75	2.37	1.48	DA6	1.51	.94	1.58	.92
DR10	1.55	1.36	1.69	1.28	DA7	1.14	1.07	1.63	.88
DR11	1.23	1.11	2.48	1.08	DA8	.88	1.04	1.44	1.03
DR12	.96	1.25	1.72	1.44	DA9	.87	1.09	1.16	.93
DR13	1.12	1.43	2.47	1.43	DA10	1.26	1.12	1.86	.96
MEAN	1.26	1.31	2.18	1.27		1.11	1.00	1.44	.89
SDEV.	.265	.303	.420	.147		.251	.121	.232	.104
HELL ROARING									
HR3	.90	1.03	1.75	1.03	HA1	1.04	.83	1.47	.89
HR4	.83	1.25	1.87	1.36	HA2	.86	1.09	1.48	1.27
HR6	.78	.98	2.00	1.14	HA3	1.11	1.08	1.24	.86
HR9	1.54	1.29	2.09	1.59	HA4	.93	1.12	1.39	.81
HR10	1.03	1.03	1.87	1.00	HA5	.82	.97	1.41	.91
HR11	2.02	1.02	1.93	2.02	HA6	1.02	1.25	1.16	.92
HR14	.97	1.25	1.88	1.06	HA7	1.06	1.15	1.20	1.08
HR15	1.08	1.09	1.52	1.50	HA8	.87	1.29	1.29	.92
HR16	1.00	1.29	1.43	0.98	HA9	.97	1.25	1.25	1.11
HR17	1.02	1.22	1.74	1.03	HA10	1.07	1.26	1.42	.85
MEAN	1.12	1.15	1.81	1.27		.98	1.13	1.33	.96
SDEV.	.379	.126	.205	.343		.101	.146	.117	.145
COMBINED									
MEAN	1.19	1.23	2.00	1.27		1.04	1.06	1.39	.92
SDEV	.326	.242	.374	.257		.197	.147	.188	.129
EXTRA									
HR5	1.38	1.61	2.35	1.46					
HR8	.96	1.21	1.53	1.18					
HR13	1.40	1.43	1.93	1.42					
HR18	1.14	1.10	2.72	1.03					
HR20	1.16	.87	2.36	1.29					
HR22	1.07	1.06	1.95	1.04					
MEAN	1.19	1.21	2.14	1.24					
SDEV.	.174	.268	.420	.185					
ALL REDDS									
MEAN	1.19	1.23	2.03	1.26					
SDEV.	.295	.242	.382	.239					

Dissolved Oxygen

Figure 1 illustrates the means and standard deviations about the means for the percent saturation of dissolved oxygen and the means of the water temperatures for the four sampling dates. Tables 5-8 list the temperature and percent saturations of dissolved oxygen for the artificial and natural redds for the four sampling dates. During the first two sampling dates the stream water was close to or slightly over complete oxygen saturation. The mean dissolved oxygen contents in both the natural and artificial redds were between 96 and 97 percent saturation during the first sampling period and between 94 and 98 percent saturation during the second sampling period. By the third sampling period, one month after redd construction, there is a noticeable drop in dissolved oxygen in both the stream and within the redds. In the third and fourth sampling periods differences are becoming evident both between the two sampling sites and between the artificial and natural redds. On June 12 the artificial redds have saturations about 6% higher than the natural redds at the Diversion reach and about 4.5% at the Hell Roaring reach. Also as of June 12, the Diversion reach natural and artificial redds averaged about 6% less saturation than those at the Hell Roaring reach.

The temperature of the water extracted from the redds for the four sampling dates was within 1 degree centigrade of the stream water temperature. Temperatures on the first sampling date were 3 to 4 degrees cooler than the next three sampling dates. The temperatures between the natural and artificial redds were similar for each reach. However, the temperatures in the Diversion reach were 1 to 3 degrees warmer than the those at the Hell Roaring reach. The influence of streamflow from Hell Roaring and Mays Creek in the Hell Roaring reach be responsible for the lower temperatures.

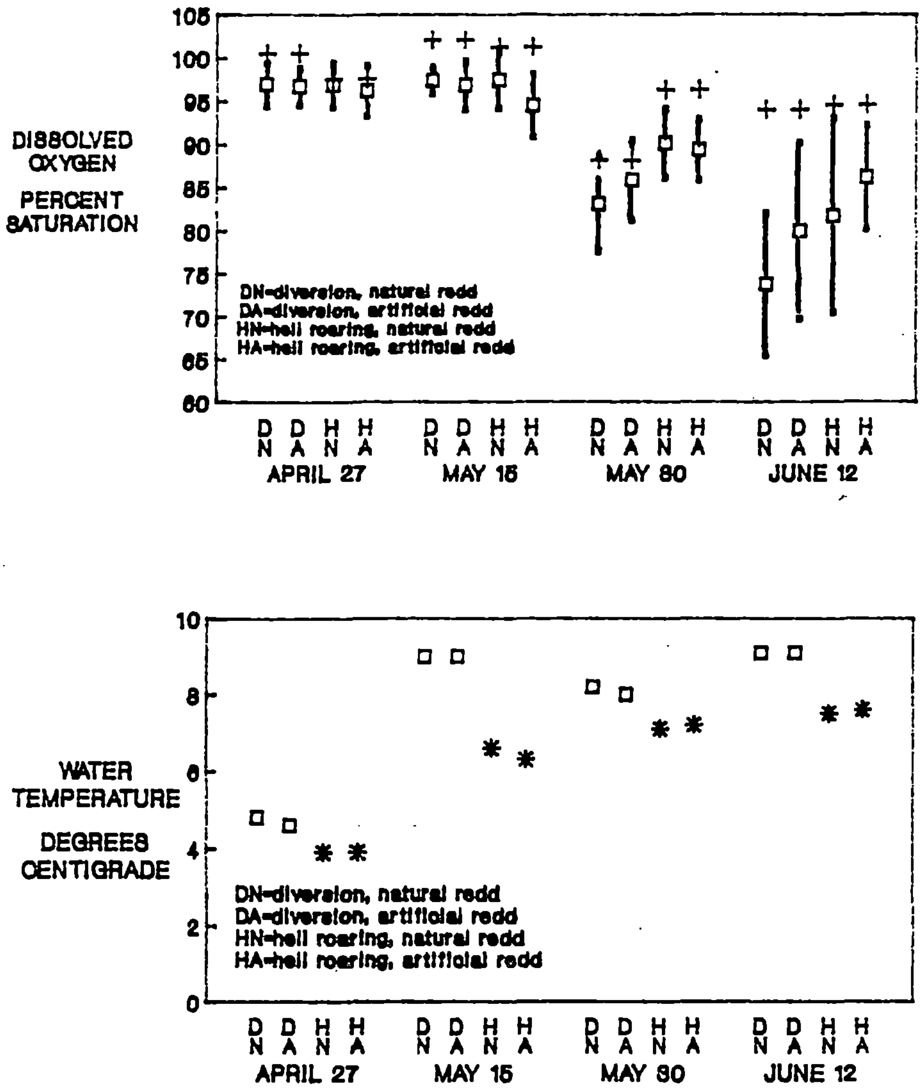


Figure 1. The means and standard deviations of percent saturation of dissolved oxygen and mean temperatures for water extracted from the natural and artificial redds.

Table 5. Percent saturation of dissolved oxygen and water temperature in natural and artificial steelhead redds and the water column near Stanley, Idaho on April 27, 1990.

Natural Redd Id	Water Temperature C	Dissolved Oxygen %	Artificial Redd Id	Water Temperature C	Dissolved Oxygen %
DIVERSION					
DR1	5.0	96.25	DA1	4.4	96.91
DR3	4.4	97.70	DA2	4.4	94.51
DR4	4.4	77.05	DA3	4.4	97.01
DR5	5.0	96.66	DA4	4.4	95.61
DR8	4.4	95.61	DA5	4.4	92.61
DR9	4.4	91.62	DA6	4.4	95.81
DR10	5.0	100.41	DA7	5.0	98.18
DR11	5.0	97.26	DA8	5.0	99.29
DR12	5.0	98.38	DA9	5.0	98.07
DR13	5.0	98.78	DA10	5.0	98.78
MEAN	4.8	94.97		4.6	96.68
SDEV.	.31	6.71		.31	2.07
HELL ROARING					
HR3	4.4	96.90	HA1	4.4	98.90
HR4	3.9	94.49	HA2	3.9	93.50
HR6	4.4	98.10	HA3	4.4	95.00
HR9	3.9	98.62	HA4	3.9	100.30
HR10	3.3	101.45	HA5	2.8	99.71
HR11	3.3	99.90	HA6	3.3	99.03
HR14	4.4	95.20	HA7	3.9	93.11
HR15	3.9	95.37	HA8	3.9	94.49
HR16	3.9	94.88	HA9	3.9	94.29
HR17	3.9	94.09	HA10	4.4	93.81
MEAN	3.9	96.90		3.9	96.21
SDEV.	.40	2.52		.51	2.89
EXTRA					
HR5	4.4	96.70			
HR8	3.9	100.49			
HR13	3.9	94.49			
HR18	3.9	93.80			
HR20	3.9	96.06			
HR22	3.9	94.59			
MEAN	4.0	96.02			
SDEV.	.20	2.44			

(NOTE: A WATER SAMPLE WAS DIFFICULT TO EXTRACT ON NATURAL REDD DR4.)

WATER COLUMN		
AT DR9	5.0	100.91
AT DR13	5.0	100.10
AT RT1	3.9	99.31
AT NW7	4.4	95.80

Table 6. Percent saturation of dissolved oxygen and water temperature in natural and artificial steelhead redds and the water column near Stanley, Idaho on May 15, 1990.

Natural Redd Id	Water Temperature C	Dissolved Oxygen %	Artificial Redd Id	Water Temperature C	Dissolved Oxygen %
DIVERSION					
DR3	8.9	98.3	DA2	8.7	96.5
DR4	8.9	63.3	DA3	9.4	102.2
DR5	8.9	96.6	DA4	8.9	97.1
DR8	8.9	96.3	DA5	8.9	97.6
DR9	9.4	96.2	DA6	8.9	93.9
DR10	9.4	96.0	DA7	9.4	98.3
DR12	8.9	99.4	DA9	8.9	96.1
DR13	8.9	99.1	DA10	8.9	93.3
MEAN	9.0	93.15		9.0	96.88
SDEV.	.23	12.14		.26	2.76
HELL ROARING					
HR4	6.7	91.0	HA2	6.4	94.5
HR6	7.8	100.2	HA3	7.2	97.3
HR9	6.7	99.2	HA4	6.4	97.7
HR11	5.6	100.0	HA6	5.6	94.1
HR14	6.7	99.4	HA7	6.1	92.7
HR15	6.7	97.8	HA8	6.1	92.7
HR16	6.4	97.7	HA9	6.7	99.0
HR17	6.1	94.3	HA10	5.6	87.8
MEAN	6.6	97.45		6.3	94.48
SDEV.	.63	3.22		.54	3.58
EXTRA					
HR5	7.8	100.0			
HR8	6.7	101.1			
HR13	6.7	94.8			
HR18	6.7	88.8			
HR20	6.1	97.9			
HR22	5.6	87.4			
MEAN	6.6	96.24			
SDEV.	.82	5.49			

(NOTE: A WATER SAMPLE WAS DIFFICULT TO EXTRACT ON NATURAL REDD DR4.)

WATER COLUMN		
AT DR9	9.4	101.7
AT DR13	10.0	102.4
AT RT1	6.4	99.7
AT NW7	8.3	102.8

Table 7. Percent saturation of dissolved oxygen and water temperature in natural and artificial steelhead redds and the water column near Stanley, Idaho on May 30, 1990.

Natural Redd Id	Water Temperature C	Dissolved Oxygen %	Artificial Redd Id	Water Temperature C	Dissolved Oxygen %
DIVERSION					
DR3	8.3	89.3	DA2	7.8	81.2
DR4	8.3	69.4	DA3	7.8	90.2
DR5	7.8	85.4	DA4	pulled	
DR8	7.8	84.5	DA5	7.8	90.2
DR9	7.8	79.7	DA6	7.8	88.6
DR10	8.3	88.1	DA7	8.3	87.1
DR12	8.6	73.3	DA9	8.3	86.1
DR13	8.3	81.5	DA10	8.3	78.1
MEAN	8.2	81.4		8.0	85.9
SDEV.	.31	7.02		.27	4.63
HELL ROARING					
HR4	6.7	83.3	HA2	6.9	87.4
HR5	7.2	96.2	HA3	7.2	90.0
HR9	7.2	90.9	HA4	7.2	96.1
HR11	6.7	94.3	HA6	7.2	92.2
HR14	7.2	90.7	HA7	7.2	88.0
HR15	7.5	90.1	HA8	7.2	86.7
HR16	7.5	87.4	HA9	7.8	90.2
HR17	6.7	88.8	HA10	6.9	85.1
MEAN	7.1	90.21		7.2	89.46
SDEV.	.34	3.98		.28	3.49
EXTRA					
HR8	6.9	96.7			
HR13	7.2	93.7			
HR18	7.2	92.3			
HR20	7.2	90.0			
HR22	6.9	86.3			
MEAN	7.1	91.80			
SDEV.	.16	3.92			

(NOTE: A WATER SAMPLE WAS DIFFICULT TO EXTRACT ON NATURAL REDD DR4.)

WATER COLUMN		
AT DR9	8.3	95.7
AT DR13	8.6	80.7
AT RT1	6.7	98.4
AT NW7	7.2	94.3

Table 8. Percent saturation of dissolved oxygen and water temperature in natural and artificial steelhead redds and the water column near Stanley, Idaho on June 12, 1990.

Natural Redd Id	Water Temperature C	Dissolved Oxygen %	Artificial Redd Id	Water Temperature C	Dissolved Oxygen %
DIVERSION					
DR3	8.9	60.4	DA2	8.9	62.5
DR5	8.9	76.8	DA4	pulled	
DR8	8.9	78.3	DA5	8.9	81.2
DR9	8.9	81.5	DA6	8.9	89.1
DR10	9.7	66.6	DA7	9.4	82.1
DR13	9.4	78.8	DA10	9.4	85.0
MEAN	9.1	73.73		9.1	79.98
SDEV.	.35	8.31		.27	10.25
HELL ROARING					
HR4	7.8	67.7	HA2	7.8	84.4
HR9	7.8	82.6	HA4	7.8	77.2
HR11	7.2	96.6	HA6	7.5	92.8
HR14	7.8	70.8	HA7	7.8	83.6
HR15	7.8	91.6	HA8	7.8	92.9
HR17	6.7	81.3	HA10	6.9	86.3
MEAN	7.5	81.77		7.6	86.20
SDEV.	.47	11.28		.36	5.99
EXTRA					
HR8	7.8	70.0			
HR18	7.8	93.5			
HR20	7.2	79.5			
HR22	7.2	83.6			
MEAN	7.5	81.65			
SDEV.	.35	9.74			

(NOTE: A WATER SAMPLE WAS DIFFICULT TO EXTRACT ON NATURAL REDD DR4.)

WATER COLUMN		
AT DR9	9.4	92.9
AT DR13	8.3	95.1
AT RT1	7.8	92.0
AT NW7	8.9	97.1

Intragravel Velocity

Table 9 lists the relative egg pocket velocities for the natural and artificial redds for the two sampling dates. For both sampling dates the mean value of the index is greater for the natural redds, suggesting higher intragravel velocities in the natural redds. Also, for both natural and artificial redds, the index decreased between the two sampling periods, suggesting a decrease in intragravel velocities over time.

Table 9. Relative intragravel velocity index for the artificial and natural redds as determined from dilution of an .05 Molar NaCl solution between 2 and 5 minutes after injection.

	NATURAL		ARTIFICIAL	
Date	Redd Id	Velocity Index	Redd Id	Velocity Index
May 1	DR11	1.78	DA8	1.79
	DR1	2.08	DA1	1.36
	HR3	1.88	HA1	1.41
	HR10	1.99	HA5	1.83
	MEAN	1.93		1.60
June 1	DR4	0.84	DA3	1.11
	DR12	1.13	DA9	1.19
	HR5	1.57	HA3	1.08
	HR16	2.08	HA9	1.29
	MEAN	1.41		1.17

Figure 2 illustrates the relationship between the velocity index and the percent saturation of dissolved oxygen for the two sampling periods. The data for the first sampling period, represented by the small darkened squares, had near or slightly above saturations irregardless of the velocity index. However, by the second sampling date (June 1) there was considerable variability in both percent saturation and the velocity index. It appears that there may be relationship between these two parameters.

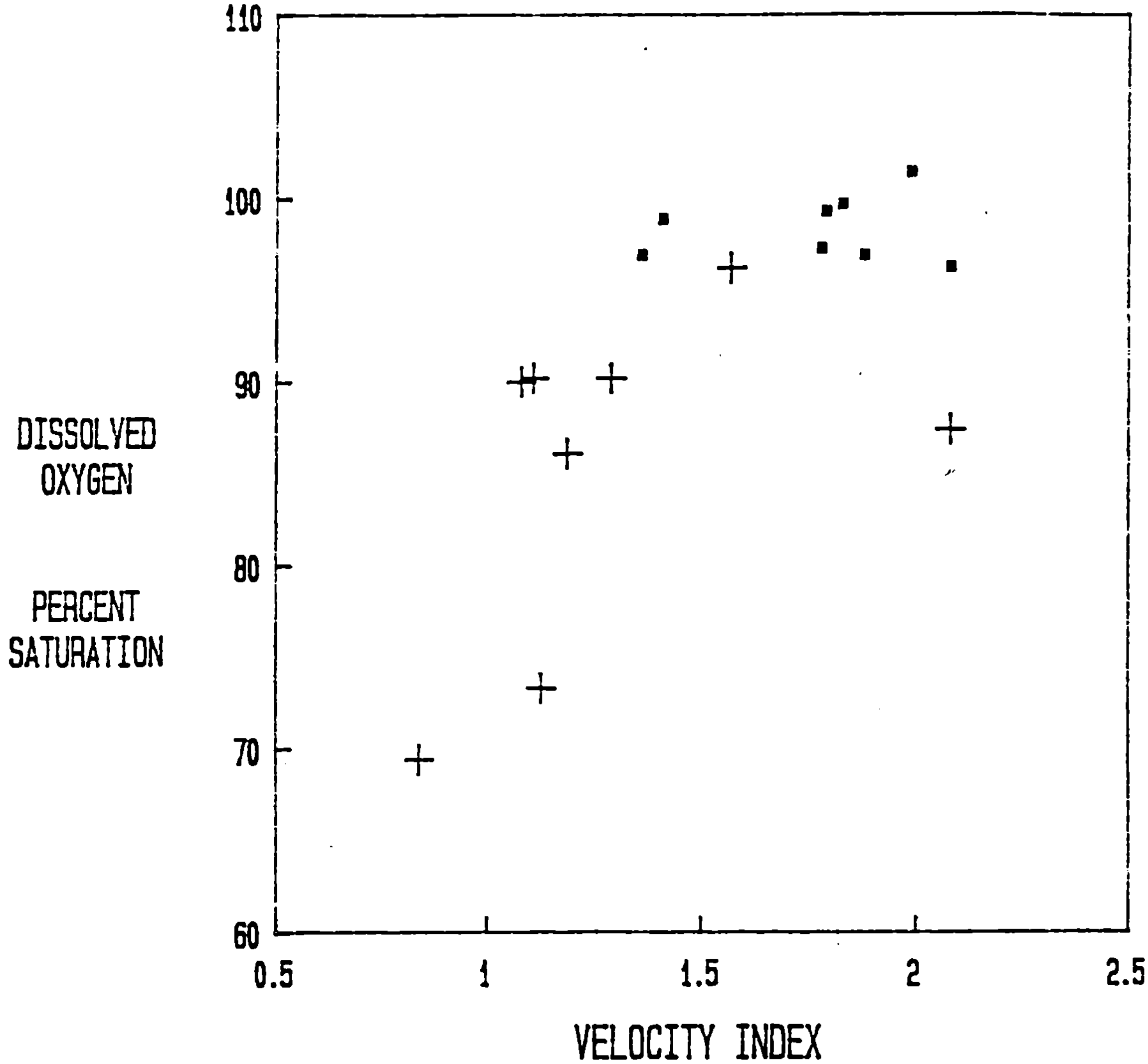


Figure 2. The relationship between the percent saturation of dissolved oxygen and the intragravel velocity index for natural steelhead and artificial redds. (The pluses represent June 1 data and the filled in boxes the May 1 data).

Particle size distribution

The mean proportions of the substrate samples which were less than 6.35mm are listed in Table 10. The data illustrates the large amount of variation between the Diversion and Hell Roaring reaches. Within sites in substrate outside of redds, the Hell Roaring reach generally exhibited larger amounts of fine sediment. Figure 3 illustrates that pits in natural redds and artificial redds in the Hell Roaring reach also exhibited more fine sediment than similar sites in the Diversion reach during the May sample.

The data also illustrate the differences between individual strata within the same site. We observed a wide variation in the percent fines between the surface strata (0-10cm) and lower strata. Data suggests that the pooled strata (0-30cm) may not reflect important differences between strata.

Egg pockets in natural redds were more prevalent in some strata. We located egg pockets in five of the eight natural redds we core sampled. Eggs and alevins were generally found in the 10-20cm strata. Egg pocket depths ranged from 9-22 cm with most located 15 to 22 cm below the streambed surface. Egg pockets in the artificial redds were generally deeper, ranging from 15-29cm with most deeper than 20cm.

Tables 11 and 12 list the Geometric Means and Fredle Indexes, respectively for the sampling sites. While increases or decreases in fine sediment were generally reflected by each measurement, the relative change sometimes differed between measurements. Figure 4 illustrates the same data set for natural redd pits in the Diversion reach in May. Although all three measurements illustrate a decrease in fines in lower strata, the relative change differs between the measurements.

We observed differences in the amount of fine sediment between the sampling sites. However, a large amount of variation occurred and few trends were evident. Figure 3 illustrates differences in fine sediment between natural and artificial redds within the 10-20cm strata sampled in May. Figure 5 illustrates differences in the Fredle Index between sampling sites in the 10-20cm strata.

The amount of fine sediment found in sampling sites also differed between May and June sampling dates (Figure 5). No consistent trends were apparent and differences may be a result of individual variation between sites.

Table 10. Comparison of the percent substrate passing a 6.35mm sieve within sampling sites, Diversion and Hell Roaring reaches, Salmon River, May-June, 1990.

Vertical Strata	Natural Redd Pit	Natural Redd Tailspill	Egg Pocket	Artifical Redd	Outside Redd	Intrusion Site
Diversion Reach						
May 1, 1990 Sample						
0 - 10 cm	23.54	15.46	ND	6.13	8.82	ND
10 - 20 cm	20.18	25.78	18.3	14.46	27.18	ND
20 - 30 cm	16.92	28.16	22.18	26.88	18.64	ND
Pooled (0 - 30 cm)	19.52	25.18	19.79	18.36	20.62	ND
June 1, 1990 Sample						
0 - 10 cm	12.22	11	ND	4.42	15.12	ND
10 - 20 cm	14.17	21.46	14.17	11.71	37.25	ND
20 - 30 cm	58.28	53.85	58.28	12.32	27.38	ND
Pooled (0 - 30 cm)	16.86	18.18	16.86	8.5	24.55	ND
Hell Roaring Reach						
May 1, 1990 Sample						
0 - 10 cm	11.37	18.49	ND	6.93	13.56	ND
10 - 20 cm	30.37	24.36	33.33	31.6	24.85	ND
20 - 30 cm	27.54	26.54	31.59	36.19	47.94	ND
Pooled (0 - 30 cm)	23.22	22.58	23.22	24.24	22	0
June 1, 1990 Sample						
0 - 10 cm	19.98	6.15	ND	13.4	28.86	ND
10 - 20 cm	29.3	18.02	ND	18.59	20.98	ND
20 - 30 cm	20.69	17.59	ND	20.49	37.58	ND
Pooled (0 - 30 cm)	24.8	12.18	ND	17.1	25.02	8.23

ND= no data, either no eggs in strata or no intrusion sample in that strata

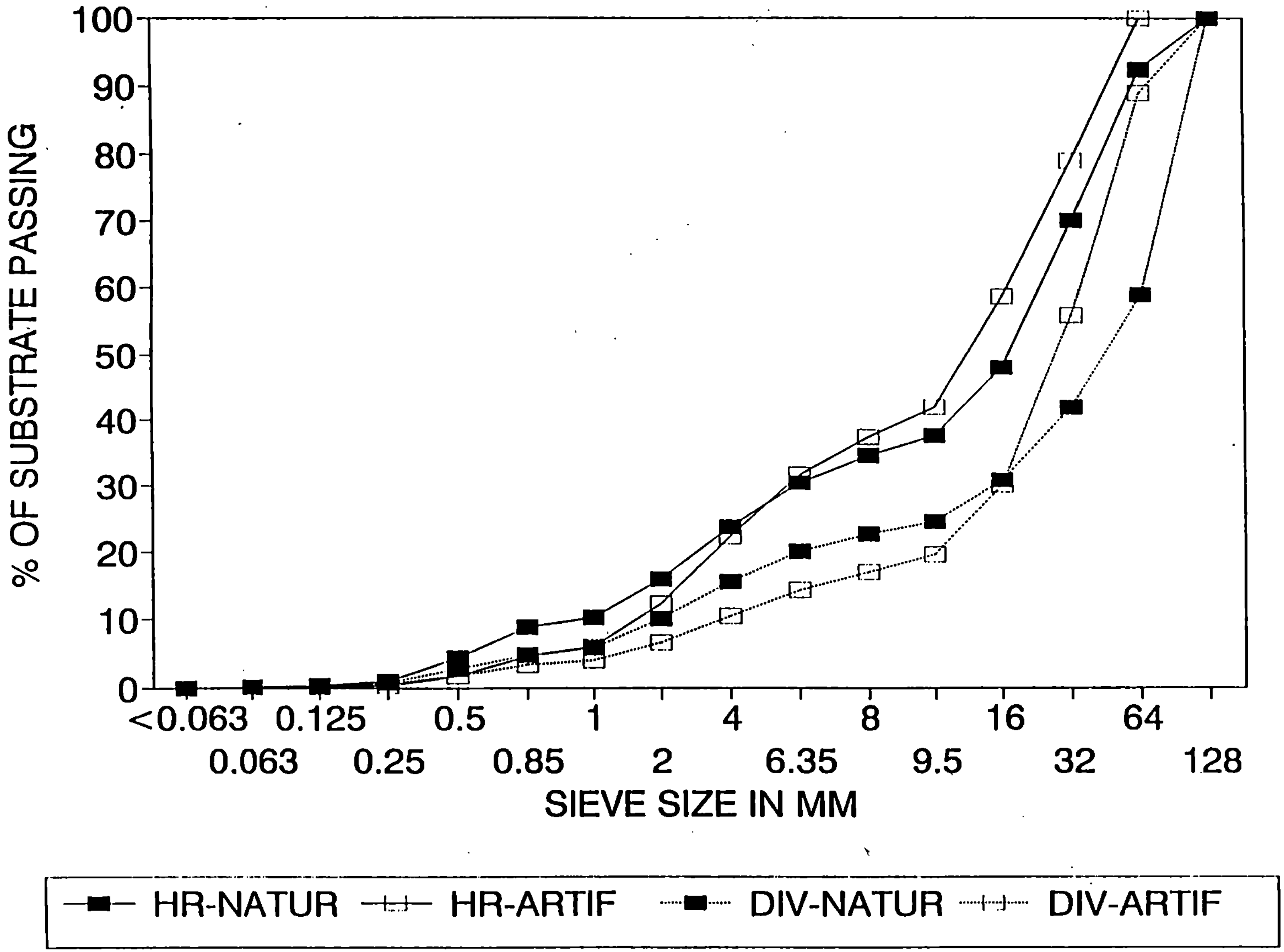


Figure 3. The percent of the substrate passing a progression of sieves, Hell Roaring and Diversion reaches, natural and artificial redds, 10-20 cm strata Salmon River, May 1990.

Table 11 Comparison of Geometric Means within sampling sites, Diversion and Hell Roaring reaches, Salmon River, May-June 1990.

Vertical Strata	Natural Redd Pit	Natural Redd Tailspill	Egg Pocket	Artifical Redd	Outside Redd	Intrusion Site
	Diversion Reach					
	May 1, 1990 Sample					
0 - 10 cm	12.18	19.12	ND	23.91	20.74	ND
10 - 20 cm	25.89	13.81	27.7	21.73	12.6	ND
20 - 30 cm	26.01	12.24	12.45	12.13	21.24	ND
Pooled (0 - 30 cm)	22.38	13.72	18.94	17.27	17.12	ND
	June 1, 1990 Sample					
0 - 10 cm	21.84	32.78	ND	34.75	28.33	ND
10 - 20 cm	31.62	27.18	31.62	24.46	8.52	ND
20 - 30 cm	3.44	5.05	3.44	22.38	13.44	ND
Pooled (0 - 30 cm)	25.09	24.54	25.09	28.41	16.43	ND
	Hell Roaring Reach					
	May 1, 1990 Sample					
0 - 10 cm	26.36	20.87	ND	25.14	9.55	ND
10 - 20 cm	12.44	16.51	8.96	12.8	13.74	ND
20 - 30 cm	35.81	13.92	53.54	10.36	5.4	ND
Pooled (0 - 30 cm)	16.56	17.5	16.55	14.86	15.14	25.86
	June 1, 1990 Sample					
0 - 10 cm	15.31	50.68	ND	17.06	14.34	ND
10 - 20 cm	12.7	21.52	ND	19.12	21.02	ND
20 - 30 cm	19.32	16.68	ND	18.76	8.3	ND
Pooled (0 - 30 cm)	14.72	31.6	ND	18.34	16.39	20.81

ND= no data, either no eggs in strata or no intrusion sample in that strata

Table 12 Comparison of Fredle Indexes within sampling sites, Diversion and Hell Roaring reaches, Salmon River, May-June 1990.

Vertical Strata	Natural Redd Pit	Natural Redd Tailspill	Egg Pocket	Artifical Redd	Outside Redd	Intrusion Site
	Diversion Reach					
	May 1, 1990 Sample					
0 - 10 cm	5.52	10.94	ND	15.24	12.77	ND
10 - 20 cm	8.75	5.52	9.67	~~10.88~~	4.38	ND
20 - 30 cm	12.9	4.47	6.47	5.37	9.24	ND
Pooled (0 - 30 cm)	7.92	5.46	6.68	7.89	7.2	ND
	June 1, 1990 Sample					
0 - 10 cm	9.68	18.46	ND	23.74	11.75	ND
10 - 20 cm	16.9	13.46	16.9	11.27	2.42	ND
20 - 30 cm	0.31	1.26	0.62	11.38	6.61	ND
Pooled (0 - 30 cm)	11.1	9.09	11.1	16.94	5.26	ND
	Hell Roaring Reach					
	May 1, 1990 Sample					
0 - 10 cm	15.6	10.37	ND	15.7	12.02	ND
10 - 20 cm	4.18	8.11	3.16	6.16	5.26	ND
20 - 30 cm	11.94	4.69	17.77	4.28	1.63	ND
Pooled (0 - 30 cm)	6.3	8.26	6.29	7.35	6.44	17.44
	June 1, 1990 Sample					
0 - 10 cm	7.47	32.12	ND	10.81	4.18	ND
10 - 20 cm	4.62	8.45	ND	8.28	9.44	ND
20 - 30 cm	12.39	9.06	ND	8.62	3.14	ND
Pooled (0 - 30 cm)	6.33	15.21	ND	9.04	5.49	11.59

ND= no data, either no eggs in strata or no intrusion sample in that strata

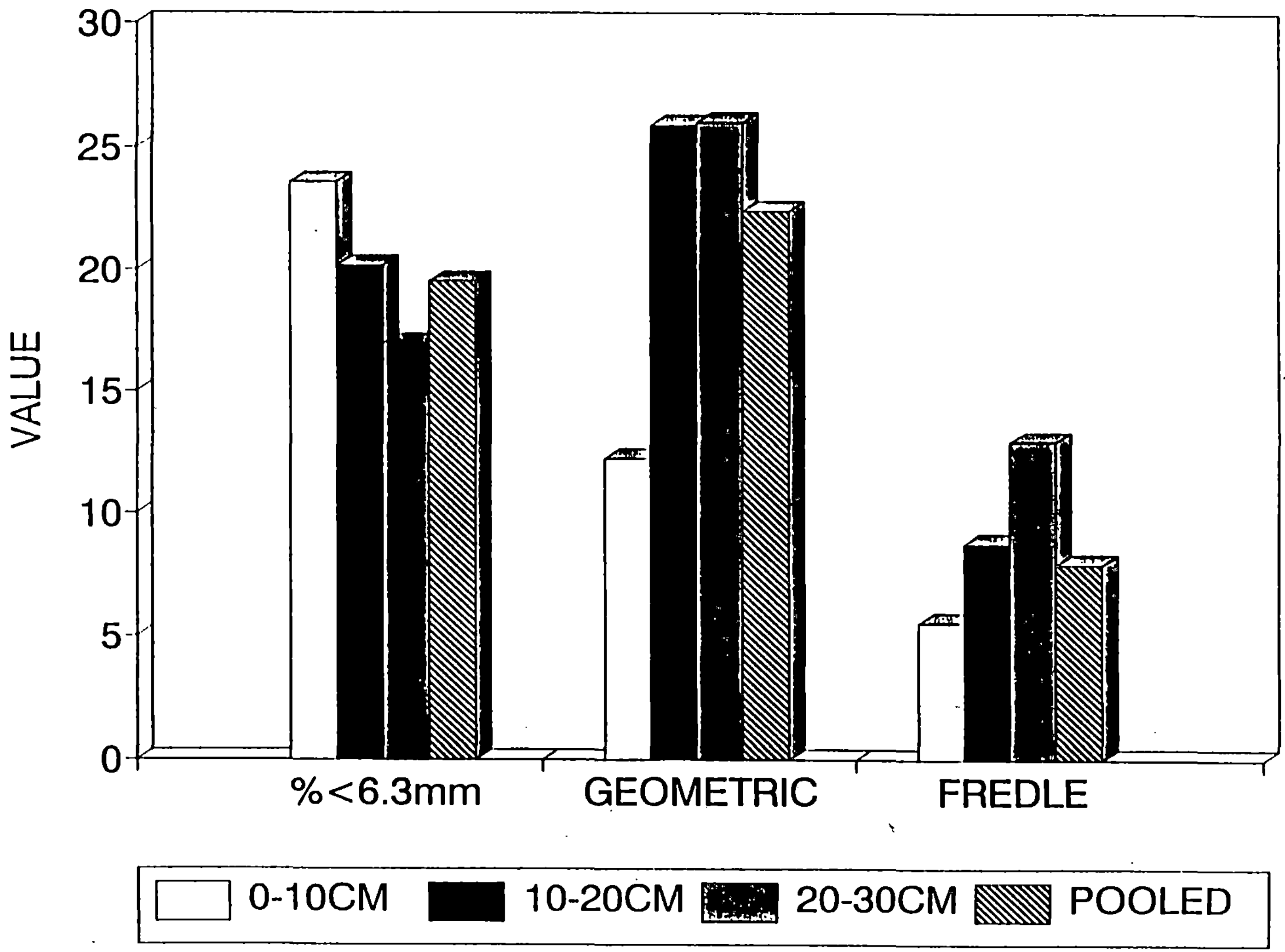
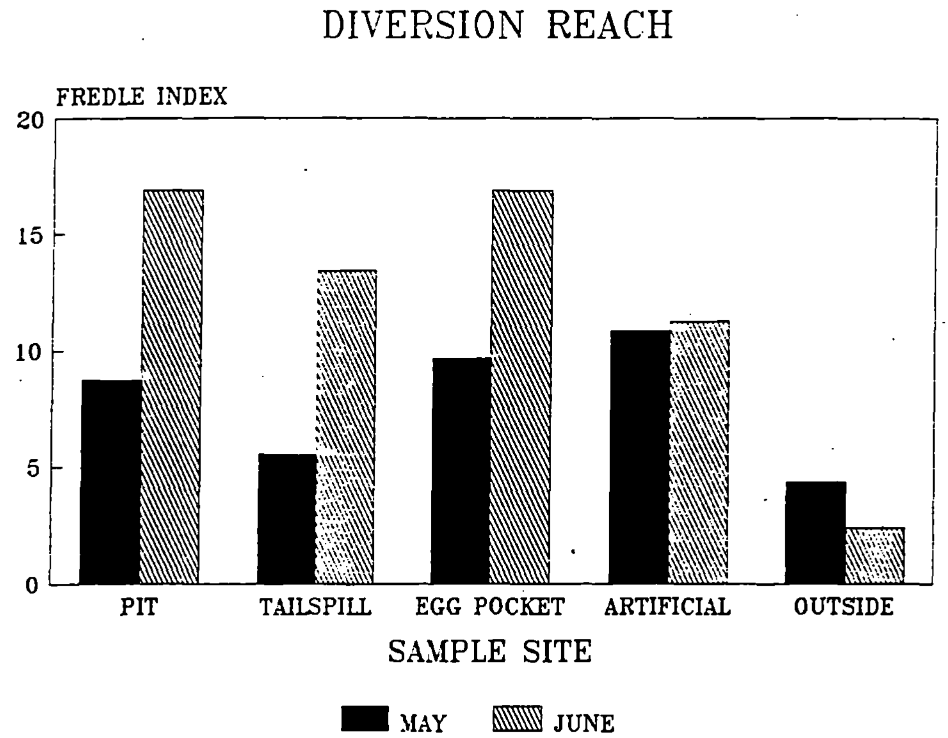


Figure 4. A comparison of the percent substrate <6.3mm, the Geometric Mean and the Fredle Index, Diversion Reach, Natural redd pits, Salmon River, May 1990.



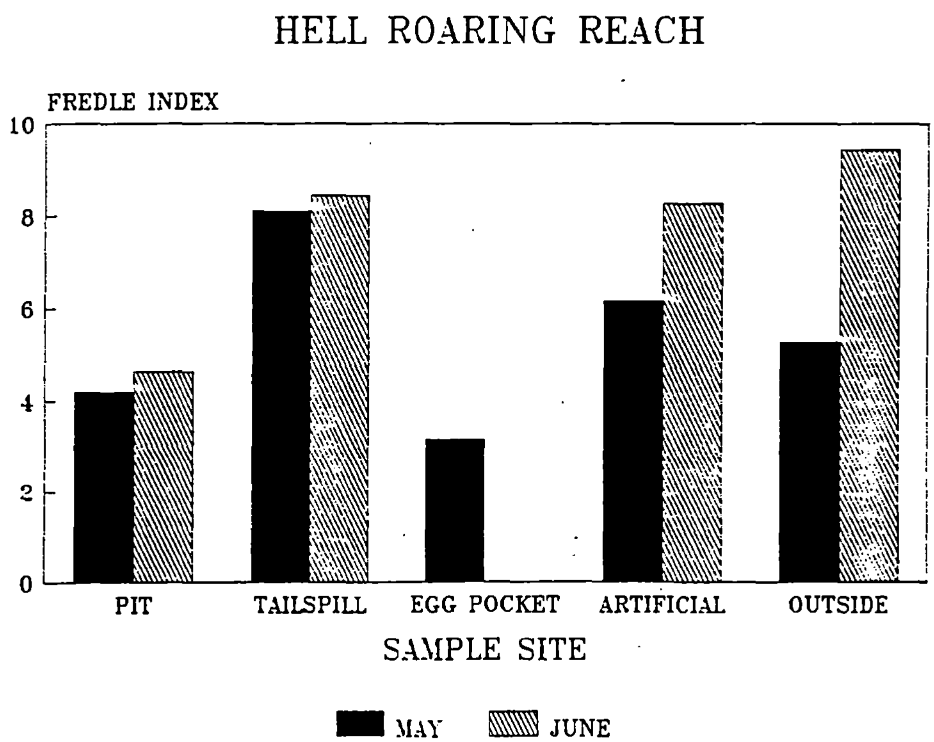


Figure 5. Comparison of Fredle Indexes by sampling site, month and reach, Salmon River 1990.

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